USAWC STRATEGY RESEARCH PROJECT

IS THERE SPACE FOR THE OBJECTIVE FORCE?

by

Lieutenant Colonel Timothy R. Coffin
United States Army

Colonel William Pierce
Project Advisor

U.S. Army War College
CARLISLE BARRACKS, PENNSYLVANIA 17013

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **07 APR 2003**	2. REPORT TYPE	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Is There Space for the Objective Force?**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Timothy Coffin;**		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army War College,Carlisle Barracks,Carlisle,PA,17013-5050,**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
See attached file.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**48**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

ABSTRACT

AUTHOR: Timothy R. Coffin

TITLE: Is There Space For The Objective Force?

FORMAT: Strategy Research Project

DATE: 07 April 2003 PAGES: 48 CLASSIFICATION: Unclassified

The Army has launched itself on a daring trajectory toward the Objective Force. It will transform the Army forces into a more lethal and devastating force through the combination of precision weapons and knowledge-based warfare. Army forces will survive through information dominance, provided by a torrent of ones and zeros sent from remote sensors and processed by on board computers. As the Army builds the Objective Force it will attempt to link systems from “mud to space” in order to create a synergistic effect between the warrior and the information sphere. Information will empower the Army’s Objective Forces. Space-based systems will be foundational building blocks for the Objective Force to achieve information dominance and satellite communications will enable knowledge based battle command on the move. Thus, the ability to link space-based capabilities to warfighting units in a timely and relevant manner is critical to Objective Force success. Army transformation plans for space to lift a heavy load for the Objective Force by using space capabilities to provide intelligence, navigation, warning and more. Nowhere is the Objective Force success more dependent, than on its ability to network together enabling information for dominant situational knowledge. This paper will address Army satellite communications needs to determine if current and future space communications can provide the capabilities the Objective Force requires to succeed. The answer requires analysis of several major areas where space communications impact Objective Force capabilities. First, why does the Objective Force need space to provide the seamless communications required for information dominance across a distributed battlefield? Second, what exists to provide the Objective Force information from ground and space-based sensors for intelligence, surveillance, and reconnaissance (ISR) as well as the warning required by the Objective Force to enable the force to see first, understand first, and act first? Third, where capability shortfalls exist in satellite communications and what can be done to provide a robust tactical information sphere needed to support transformational capabilities on future battlefields?

TABLE OF CONTENTS

ACKNOWLEDGMENTS

I would like to acknowledge the contributions of Dr. Williamson Murray in his helpful editing of this research project. I also would like to thank my advisor, Colonel William Pierce, for his patient efforts in allowing me to reshape my over ambitious project three times and helping me finish the Strategy Research Paper.

LIST OF ILLUSTRATIONS

LIST OF TABLES

IS THERE SPACE FOR THE OBJECTIVE FORCE?

> The ultimate goal of Army Transformation - the Objective Force - will consist of lighter but highly lethal, mobile, and survivable formations that arrive in an area of operations ready to fight and fully synchronized with other elements of the joint Force. Our successful transformation to the Objective Force will depend to a great extent on our ability to develop and operationalize new and improved space-based capabilities. As a space-empowered force, the Objective Force will routinely exploit the overhead constellation of national, commercial and military space platforms for intelligence, focused surveillance, and area reconnaissance; long-haul communications; early warning of missile attack; positioning, timing, and navigation; missile defense; and access to the Global Information Grid… What exactly the Objective Force will look like is not yet certain. We know it will be a space-empowered military force able to deliver precisely calibrated effects, from taking a picture to dropping a precision munition, at any time and anywhere on Earth.[1]
>
> — LTG Joseph M. Cosumano Jr.

> The Objective Force is to be more strategically responsive and dominant at every point on the spectrum of military operations than the Legacy Force. It will provide the Nation an array of more deployable, more agile, more versatile, more lethal, more survivable, and more sustainable formations that are affordable and capable of reversing the conditions of human suffering rapidly and resolving conflicts decisively. These capabilities will enable the Objective Force to win on the offense, to initiate combat on their terms, to gain and retain the initiative, build momentum quickly and win decisively.[2]
>
> — General Eric K. Shinseki

The Army has launched itself on a daring trajectory toward the Objective Force. That force represents an innovative model of warfare, embracing new information technologies while leaving industrial age tools behind. It will transform the Army forces into a more lethal and devastating force through the combination of precision weapons and knowledge-based warfare. Objective Forces will survive through information dominance, provided by a torrent of ones and zeros sent from remote sensors and processed by on board computers. Precision strike and information dominance represent a quantum leap from brute force legacy systems such as the M1A1 Abrams tank. The realties of warfare in the twenty-first century will relegate the Army's heavy forces to a more limited set of missions. As the Army builds the Objective Force it will attempt to link systems from "mud to space" in order to create a synergistic effect between the warrior and the information sphere. Information will empower the Army's Objective Forces. Space-based systems will represent the foundational building blocks for the Objective Force to achieve information dominance. Satellite communications will enable knowledge-based battle

command on the move. Thus, the ability to link space-based capabilities to warfighting units in a timely and relevant manner is critical for Objective Force success.

WHY THE OBJECTIVE FORCE NEEDS SPACE

WHY AN OBJECTIVE FORCE?

The pace towards the Objective Force has stirred up much controversy. For many, the need for an Objective Force is not apparent. Their vision of future threats suggests that the status quo with incremental improvements in legacy weapon systems is sufficient. They point to successes enjoyed by United States forces over the past decade and for the need of heavy armored forces to counter threats by potential adversaries. Those advocating a rapid advance towards the Objective Force have a different view of history and the future. Led by the Army's Chief of Staff, they see land power as a critical tool for the nation's defense, one now marginalized because of its inability to address many of the nation's needs. Both groups envision the need to master a powerful opponent, but those advocating the Objective Force seek new and more flexible approaches.

To achieve the flexibility required for a more agile and effective force, the Army's mass must dramatically change. One can review the legacy force as a sumo wrestler with tremendous strength, but requiring a commensurate amount of support and sustenance. During the 1991 Gulf War, after taking five months to deploy, United States armored divisions crushed Iraqi forces in their path. The Army's new vision is more like that of a samurai warrior capable of rapid, decisive movements. While this samurai may be less than half the size of the legacy force and looks puny in comparison, enhanced knowledge and agility will allow him to appear unexpectedly and to apply the right force to destroy his enemies.

Army transformation plans for space to lift a heavy load for the Objective Force by using its capabilities to provide intelligence, navigation, warning, and more. Nowhere is Objective Force success more dependent than on its ability to network together enabling information for dominant situational knowledge. This paper will address Army satellite communications needs to determine if current and future space communications can provide the capabilities the Objective Force requires to succeed. The answer requires analysis of several major areas where space communications impact Objective Force capabilities. First, why does the Objective Force need space to provide the seamless communications required for information dominance across a distributed battlefield? Second, what exists to provide the Objective Force information from ground and space-based sensors for intelligence, surveillance, and reconnaissance (ISR) as well as the warning required by the Objective Force to enable the force

to see first, understand first, and act first? Third, where capability shortfalls exist in satellite communications, what can be done to provide a robust tactical information sphere needed to support transformational capabilities on future battlefields?

THE ARMY VISION:

See First, Understand First, Act First, and Finish Decisively-- Army Transformation seeks a symbiotic merger between technology, people, organizations, processes, concepts, and doctrine in order to create the Objective Force. It aims to knit together emerging and complementary ways, as if creating a master tapestry. With this symbiosis, transformation should result in a more responsive, deployable, agile, versatile, lethal, survivable, and sustainable force. The Army's Transformation roadmap calls space the "key enabler" to provide efficient and lethal Army forces to the joint force commander.[3] A key enabler is similar to key terrain in that it can provide decisive advantages. Space enablers must provide the Objective Force with such a decisive advantage. The importance of such an advantage compels officers to clearly understand the space linkages and how they interface with Objective Force capabilities.

The need for space capabilities permeates the Objective Force from the actions required at home before deployment, through rapid redeployment after a conflict. Following the space cords that weave through the design of the Objective Force highlights the contributions expected and required from space-based capabilities. At the most basic level, the Objective Force requires three things from space to realize its operational capabilities;

- weight reduction, resulting in increases in responsiveness and agility
- information dominance to see first, understand first, and act first
- control of the space dimension of the battlefield to ensure dominant space superiority when needed

Space-based systems increase the deployability of the Objective Force by enabling a dramatic reduction in the force's mass. The space segment for most operations is already available and ready to support worldwide operations. With space forces predeployed they are ready to provide key intelligence, communication, navigation, weather and missile warning support to entry operations, where no other infrastructure exists.

Space Impacts All

Objective Force Design Principles

Responsive	**Deployable**	**Agile**
Versatile	**Lethal**	**Survivable**
	Sustainable	

FIGURE 1 OBJECTIVE FORCE DESIGN PRINCIPLES

Space is also the most efficient domain for many functions. For example, land-based communication networks require retransmission nodes to maintain line of sight across the battlefield. To overcome such barriers, Army forces seize high ground to emplace communications and observation nodes and to deny that advantage to the enemy. Each land-based communications node requires personnel, equipment, generators, life support, fuel, resupply, protection, and command and control. At levels above the deployed force more soldiers and infrastructure have to maintain the flow of material into theater and push logistic support forward. Space systems have already captured the high ground. Migrating Objective Force communication networks to a space enabled communications architecture eliminates an entire slice of legacy support forces.

Space systems increase the lethality of the Objective Force and reduce the number of weapons and munitions required in a number of ways. Precise knowledge of friendly and enemy forces, combined with precision weapon systems, represents a devastating combination. Historically, Army forces have lacked the ability for precision engagement beyond line of sight. To compensate for the lack of precision, the Army has often substituted mass. For example, during the Korean War one artillery battalion fired 14,425 rounds in a twenty-four hour period of time. Units found themselves positioning the guns based on where the rail lines were instead of where they could be most effective in order to allow offloading directly from railcars to gun positions.[4] Space-based knowledge of targets combined with weapons guided by space-based navigation provide a quantum reduction in Objective Force mass, while increasing speed.[5]

Further weight reductions for the Objective Force will occur through the use of space-based information to dissipate the fog of war. Carl von Clausewitz coined the term “fog of war” in his work “On War” to describe the uncertainties and ambiguities that characterize the conduct of war at every level. The fog of war has represented a barrier between the information needed and those making decisions that impact the battle. Many of the improvements in military

technology underway today represent attempts to reduce the barriers to a transparent battlefield. Radar represented an effort to find where enemy ships and planes were and where they might strike. Night vision devices, aimed at taking away the fog of night, and satellites were means to sense enemy actions and hint at his intentions. In spite of new technology, the fog of war has persisted.

> Even with radical improvements in satellite imagery, the use of night-vision goggles and the Predator, technology cuts through only some of the fog. Gigabytes and streaming video are no guarantee that people will learn everything they want to know or even see the same thing.[6]

The most deadly day for American forces in Afghanistan serves as a reminder that fog and friction in war still exist and may be the decisive factors during volatile, uncertain, complex and ambiguous times. When asked, "What happened" in the incident on 4 March 2002 where seven United States servicemen lost their lives in combat, Secretary of Defense Donald Rumsfeld replied "We may never know."[7] High-Tech weapons and state of the art intelligence failed to merge disparate bits of information required to understand the battlefield, while the events were occurring. While some level of the fog of war will always persist, there are ways to reduce and deal with uncertainty.

The traditional way of dealing with uncertainty has been to bring more people, firepower and supplies to provide resources to deal with the unexpected. Unfortunately, deploying more inevitably slows the force's responsiveness and agility. If the commander does not know where or how large the enemy force is, his tendency is to bring more forces. If he does not know when he will encounter the enemy, his moves will be cautious, and he will add more armor. When forces are not sure where the next resupply will occur, they order more and are reluctant to attack until the ammunition arrives. American history from the Civil War through to the First Gulf War is replete with opportunities lost in military campaigns due to such factors. Space cuts through fog and uncertainty with its systems that can, at times, reduce the need for mass to mitigate risk and uncertainty.

Lighter combat systems, empowered by new sources of information, provide agility and responsiveness to the Objective Force. A responsive force masters time, distance, and momentum to meet the challenges of tomorrow's warfare. Space-based sensors can feed the Objective Force's need for knowledge before deployment and are key to situational awareness during forced entry and subsequent operations. Such sensors along with space-based communications ensure the Objective Force arrives rapidly, fully synchronized, and ready to

fight. Space increases the force's agility by providing information for situational understanding and the means for its dissemination. Space systems that provide information dominance for combat operations also provide communications and information support for peacekeeping, peace enforcement, and humanitarian operations, thus enhancing the Objective Force's versatility. Space then plays a major role in enabling the Objective Force.

DO SPACE COMMUNICATIONS MEET OBJECTIVE FORCE NEEDS?

"Space to mud" connectivity is more than just a bumper sticker; it is the reality of the task required for the success of the soldier deep in the muck of battle. Space to mud must reflect the attitude, practice, and organization of the Objective Force.[8]

THE NEED FOR SPEED – KNOWLEDGE DEMANDS INCREASING

The ability to pass information has always been critical to military forces. Nevertheless, in recent years the demand for data has exploded. In ancient warfare, messengers carried commands, and state of the art communications was a good runner. Phidippides' run from Marathon to Athens in 490 BC to warn the Athenians of the approaching Persian Navy represents an example of such communications, limited in both speed and distance. Larger empires required more efficient means of communications. By 37AD state of the art for the Romans was a relay system for complex messages and a wireless digital-optical communications system to transmit information at the speed of light. This speed of light system used flashes of light from a polished metal mirror to send coded messages -- a simple forerunner of fiber-optic communications. Napoleon used a similar system to pass signals from station to station at a rate of approximately ten signals per minute. This system could relay a single signal from Paris to Calais in about three minutes. The American Civil War saw a dramatic jump in the speed of communications with the first widespread use of the telegraph. The most skilled operators could achieve a speed of forty-two words per minute, which would equate to the modern scale of thirty-two bits per second. By the end of the Civil War, Grant was using the telegraph to control nearly a half a million soldiers.

World War I saw relatively small changes in the speed of communications. By World War II the telephone and radio had dramatically improved voice communication, but the speed of data transmission had only doubled from in the Civil War. The advent of computer technology, however, changed everything as is shown by the logarithmic rate of increase in Figure 2. By the Gulf War, single data circuits were transmitting data as fast as 256 Thousand Bits (Kbs) per second, an increase of more than 3,600 times in only forty years.

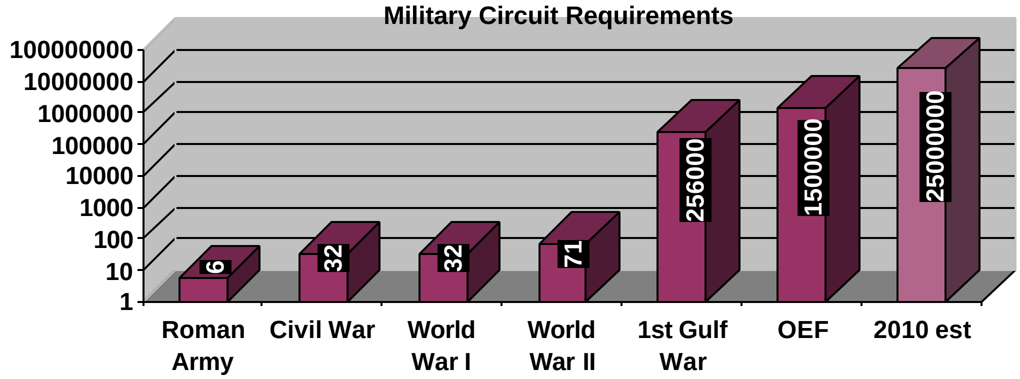

FIGURE 2 INCREASE IN DATA RATES

The need for speed has continued and bandwidth[9] requirements continue to rise. Recent conflicts have demonstrated the need for circuit data rates in combat areas with 1.5 megabits. During Operation ENDURING FREEDOM, Unmanned Arial Vehicles consumed as much as 48 Million Bits (Mbs) of bandwidth per aircraft. Put in perspective, the amount of bandwidth consumed by a single Unmanned Arial Vehicle, was half the bandwidth used during the Gulf War to support 500,000 troops. At the height of the war in Afghanistan a force one tenth of the size of the Desert Storm force used 600 percent more bandwidth. This increase in a single decade equates to 6,000 percent, when adjusted for the size of force employed.[10]

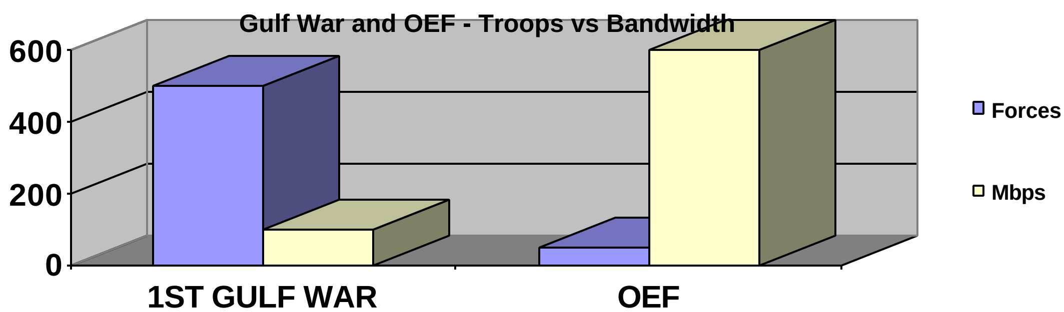

FIGURE 3 BANDWIDTH INCREASE BETWEEN 1991-2002

The increase in data flow provides key information to legacy forces, but only begins to hint at the demands an Objective Force will place on communications systems.

Not only has the amount of data exploded, but the number of sites that need data has multiplied as well. During the Civil War only commanders of armies and corps required long-range communications to conduct military operations. In contrast, the Objective Force requires that individual combat platforms and soldiers have a high level of access to digital data

immediately upon entry into the battle space. These formations will fight in a more dispersed fashion than ever before. The highly mobile platforms of the Objective Force will require digital terrain products to provide soldiers the knowledge of how to mask and transit the terrain without exposure to hostile fires. While providing critical protection, the same attributes that make this force faster, more survivable, and lethal, also make it more difficult to communicate with other Army entities in the force. Future forces will transmit and receive information through a worldwide supporting communications infrastructure known as the Global Information Grid. If disconnected from the Global Information Grid (GIG), Objective Force elements lose connectivity with long-range sensors as well as the enabling information and knowledge pushed from reach-back centers located far from the conflict. Disconnected units will lose their ability to see enemy forces and identify friendly forces. The result will be a force more vulnerable to attack as well as an increased vulnerability for friendly-fire incidents. In many cases, these forces must access space-based communications, when unable to connect with terrestrial line of sight communications systems.

OBJECTIVE FORCE CONCEPT

The Objective Force units designed to close with and engage enemy forces are Units of Action (UofA).[11] Such brigade size units are capable of conducting full-spectrum military operations. The Objective Force concept calls for forces to be ready for operations on arrival in the area of operations and to maintain information dominance while on the move. Units of Action soldiers will possess a family of innovative platforms collectively called the Future Combat System. To reach its operational capabilities the Future Combat System and other systems in the Units of Action must function as a networked system of systems and create high-capacity mobile ad-hoc networks with anti-jam and low probability of detection while forces are moving. Such a mobile network requires large increases in bandwidth in comparison to the paucity of the spectrum available now to Army forces, especially to units at brigade level and below.

> …FCS Communications, the enabler for FCS at large, is likely to be critically dependent on the use of airborne (and space-borne) assets due to limited LOS connectivity in complex terrain and foliage…. Terrestrial communications alone will not be adequate to support FCS; airborne and SATCOM networks will have to become critical parts of the FCS system, rather than 'opportunistic luxuries'.[12]

The Objective Force will depend on space-based communications from before it deploys until it returns to home station. After alert, Objective Force units at home station connect to the

Global Information Grid via high bandwidth fiber optic connections to obtain situational awareness and intelligence. Space-based sensors provide near real time imagery, intelligence and geospatial information about the area of interest and the area of operations. This information is relayed to commanders and staff by transmitting sensor data from space through ground relays to support operational planning. Large satellite dishes at fixed locations linked to fiber optic backbones maximize the throughput of space-based data. While this communications architecture supports much of today's home station needs, it will require continued upgrades to support the Objective Force's deployment. Once the Objective Force unit begins deployment, space-based communications will link sensors, networks and operational units in order to facilitate the transfer of knowledge to enroute forces. That capability will allow the commander to communicate and adapt to changing situations in the objective area. Once the Objective Force has entered into the area of operations, it begins to employ organic sensors to augment the space-based capabilities, which enabled its entry. Today, once army units deploy and are in motion, their ability to receive high bandwidth communications remains limited. The next section will discuss military communications capabilities.

MILSATCOM

Military satellite communications currently reside in three major bands: Ultra High Frequency (UHF), Super High Frequency (SHF) and Extremely High Frequency (EHF). Each frequency has unique characteristics that suit them for different missions.[13]

UHF Communications

The United States Navy operates the UHF constellation of satellites and provides the primary support to mobile users. The Navy initially developed UHF communications and launched the first generation of spacecraft called FLEETSAT to support naval aircraft, ships, and submarines. The current generation of satellites on orbit is called UHF Follow On (UFO). UHF signals broadcast from such satellites penetrate weather, foliage, and other materials such as reinforced concrete. Units can receive their signals using relatively low-cost lightweight radios with omni-directional antennas. These characteristics make UHF highly suited for mobile operations. The drawbacks to UHF lie in the fact that it provides low data rates in comparison to current needs, while the spacecraft require large antennas with significant power. These systems typically support data rates less than 16 Kbs. UHF communications are also relatively easy to jam.[14]

The Navy operates a fleet of UHF satellites that augment line of sight radio systems and provide the long-range point-to-point voice communications with low data rate connectivity that is critical in extended operations. Each of these geosynchronous[15] 60-foot long satellites has a total of thirty-nine channels with a combined bandwidth of 555kHz.[16] Each theater of operations normally has two UHF satellites in sight. If the theater is not sharing satellites with other combatant commanders and assuming both satellites are fully operational, there would be 78 channels supporting a theater with a maximum total UHF capacity of 1.1Mbs. In actual use the capacity of the satellites is reduced because channels dedicated to voice circuits optimize command and control voice communications instead of data throughput.[17] In addition to supporting the Joint Force Commander, the constellation provides support to the Army, Navy, Air Force, Marines, Special Operations Forces, State Department, National Agencies and Presidential Communications to the theater.

Admiral Blair described the UHF situation in his theater in his testimony before Congress in the following terms: "…limited Ultra High Frequency (UHF) SATCOM capacity over this AOR (*area of responsibility*), is fast becoming a factor in my ability to command and control forces…. SATCOM connectivity to our highly specialized forces is more critical than ever before."[18]

Super High Frequency (SHF) Communications

SHF communications are today's SATELLITE COMMUNICATION workhorse for the Department of Defense (DoD). The Army operates the payload on these satellite systems, which constitute the Defense Satellite Communications System (DSCS). The five primary satellites located in figure four provide global coverage with high capacity SHF communications. A single DSCS III satellite provides nearly as much communications capacity as the entire constellation of UHF satellites. The first DSCS satellite, launched in June of 1966 weighed only one hundred pounds and could relay only one voice, or data channel. Only generation II and III DSCS satellites are operational today. The first of the current generation of DSCS III satellites was launched in 1982, while the newest DSCS satellite, launched on 10 March 2003, weighs over sixty times the weight (6,025lbs) of its predecessor. The most recent satellite to launch, manufactured in 1978, as a ground test satellite was refurbished twice (most recently in 1995) to update its capacity before its launch into space.[19] While this satellite provides capabilities indispensable to the health of the constellation, the DSCS III is virtually unchanged by the needs of transformation from its Cold War design. SHF systems nonetheless are critical to Army forces due to their higher capacity. Disadvantages of SHF systems include their higher cost and their need for larger ground antennas to maximize data throughput.[20]

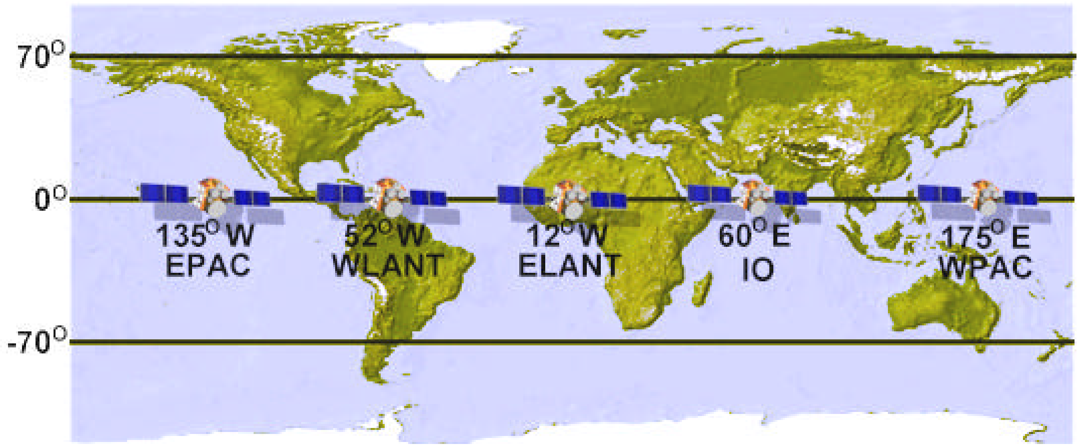

FIGURE 3 DSCS PRIME SATELLITE LOCATIONS

Antenna size is a major factor influencing data throughput in satellite communication systems. To maximize the capacity of the Defense Satellite Communications System (DSCS) constellation, primary earth stations have antennas as large as sixty feet in diameter that are anchored in huge concrete footings for stability. When the user is unable to use an optimally sized antenna, the amount of data it is able to receive decreases. For example, a DSCS receiver with a four-foot diameter dish would receive 256 Kbps, while a seven-foot antenna would have seven-fold increase to 1.7Mbps from the same satellite signal strength. Conversely a vehicle sized eighteen-inch antenna would only receive a 64Kbs data stream from the same radiated power from the satellite.[21] Increasing the power of the signal from the satellite and using larger antennas on the space segment can provide additional gain to overcome some of the data rate problems mobile users experience, but such solutions have drawbacks as well. Larger satellite antennas are extremely costly and complex structures that increase the cost and risk associated with the satellite launch. Increasing satellite broadcast power for users with small antennas decreases the power available to support other users.

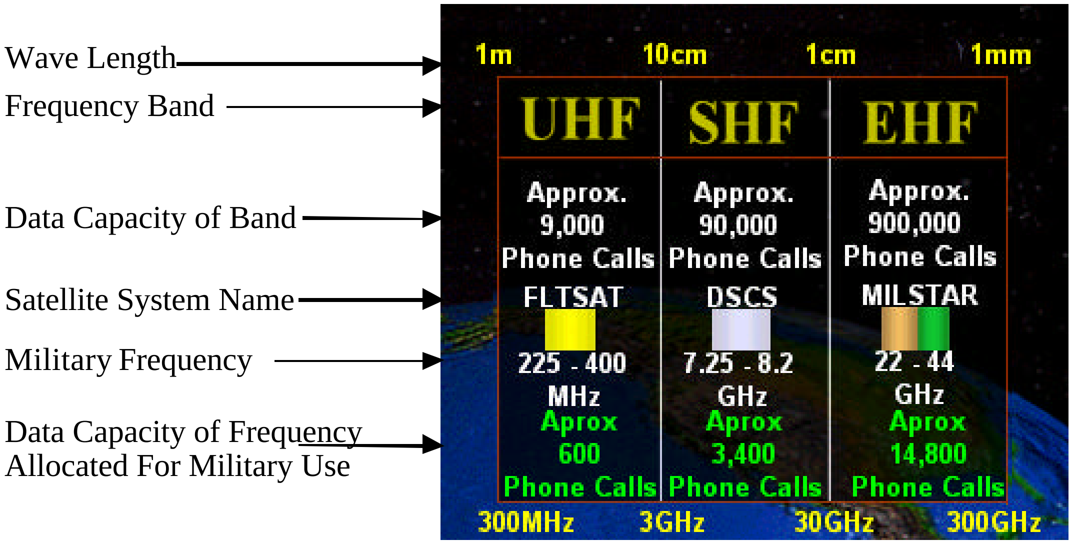

FIGURE 4 RELATIVE CAPACITIES OF SATCOM BANDS UHF, SHF AND EHF.

EHF Communications

EHF communications were originally developed to transmit Emergency Action Messages (EAM) and voice instructions for command and control of nuclear weapons. These preformatted messages did not require a high data rate, so that a maximum data rate of 2.4kbs was selected.[22] This small trickle of data is mixed with a flood of up to 40Mbs of data generated from a secure cipher, which is so complex that the pattern will not repeat itself for hundreds of years. The resulting transmission is a complex waveform resistant to jamming and interruption. While this is highly desirable for nuclear command and control, it represents a very inefficient use of the spectrum to transmit large amounts of data. While the two original satellites only supported low data rate transmissions (75bps – 2,400bps), the final four were constructed with a medium-data rate package that supports T1 size channels (1.54Mbps).[23] Three of the four satellites achieved orbit on launch and are currently supporting military operations, but MILSTAR-2 F1 was placed in a useless orbit during its launch in April 1999[24] leaving the constellation significantly short of its anticipated capacity. EHF communications represent the area with the most growth potential for Army Objective Force operations due to the high data capacity and smaller antenna sizes. EHF communications are not without their drawbacks. EHF systems require high levels of technical sophistication, are costly and more affected than lower frequencies are by rain fade, which can disrupt communications during periods of heavy rain or dust storms.[25] Figures five and six provide a relative comparison of the three spectrum military satellites operate in.

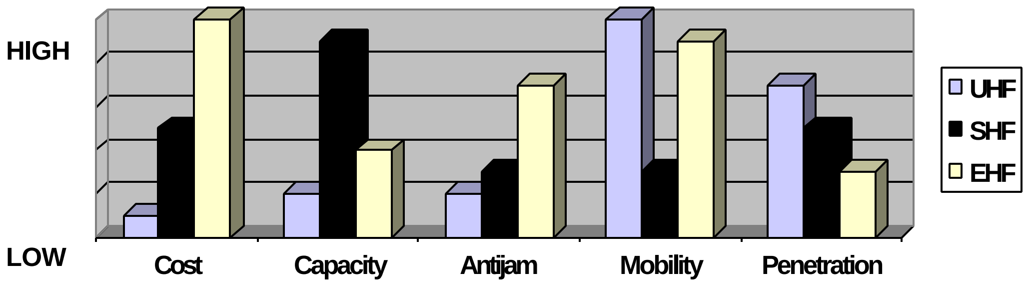

FIGURE 5 DIFFERENCES IN SATCOM BANDS

COMMERCIAL SATCOM

When military satellite communications are unable to meet the demands of a crisis, the Department of Defense turns to commercial communications providers to fill the void. While fiber optic communications have rapidly linked the digital infrastructure in the United States and even stretched to major installations overseas, they have little utility in reaching the last leg of the journey to soldiers and their combat systems. Commercial satellites provide critical augmentation to push data to forward bases and command and control hubs. When available, most wide band commercial communications can integrate into forward airfields and base camps to augment military communications. These arrangements are generally costly as the Department of Defense must purchase hardware, software, technical support, maintenance and satellite time to create a functioning communications pipeline.

To ensure success of commercial satellite business ventures investors normally require customer contracts before the satellite is built and launched. Businesses launch few commercial satellites on a speculative investment model that leaves large amounts of unused bandwidth for sale. In most cases this leaves insufficient commercial capacity available on the spot market for short-term lease to meet military's surge requirements and longer-term shortfalls. That is not to say that commercial systems have not provided critical support to military operations.

Operations DESERT STORM, ALLIED FORCE, and ENDURING FREEDOM all turned to commercial providers for significant levels of support, when the theater of operation had little ground infrastructure and military systems were fully utilized. In support of ALLIED FORCE the Department spent over $20 million to augment satellite communications for the eighty-seven day conflict. Forces supporting OPERATION ENDURING FREEDOM needed 567 megabits per second of satellite communications. Military satellites provided only 35 percent of the satellite communications needs while commercial sources provided 65 percent.[26] With luck (that spare

bandwidth was available) and at considerable cost, the Defense Information Systems Agency secured the bandwidth and over time, all of the hardware, training, and integration engineering needed to meet the minimum needs of U.S. forces was in place. In addition to the cost, the use of commercial satellite communication resulted in a significant delay required for procurement, training, and integration of commercial systems, which were unfamiliar to the deployed force. Soldiers fortunate enough to have Iridium phones relayed information through units in the United States to pass messages back to their higher headquarters when unable to make critical connections through dedicated DoD systems. Units that purchased laptop size commercial satellite communication terminals from International Maritime Satellite Corporation (INMARSAT) could connect at speeds up to 64Kbs to transmit orders, download small data files and slowly transmit imagery.

Commercial systems play a supporting role in military communications, but have too many shortfalls to provide support to key warfighting functions. Commercial systems are not designed to support military operations. Satellites and ground equipment are not universally compatible so that the equipment used on one operation may or may not work for the next operation. Satellites are not designed to support encryption and lack hardening and the ability to detect enemy physical, electronic or cyber attacks. No existing commercial systems can provide the data levels, security, global coverage, user terminals, and compatibility required for mobile command of Objective Force units. Commercial augmentation can provide support to the stationary enabling forces in support of major contingency areas, if multiyear leases are negotiated which addresses the full range of support issues that commercial augmentation brings.

SPECTRUM

Radio spectrum is a finite resource, regulated under international law and by a United Nations body called the International Telegraphic Union (ITU).[27] Within the United States the Federal Communications Commission (FCC) controls frequency allocation.[28] In recent years, significant portions of the bandwidth used by the military have come under attack from private industry seeking additional frequencies for commercial activities. Attempts to reallocate military frequencies to commercial sectors will undoubtedly become more aggressive, as competition for this finite resource becomes more intense in an information based economy. Today a United States Army heavy division already has over 10,700 individual emitters that use a portion of the frequency spectrum.[29] Loss of frequency spectrum can seriously hinder military capabilities and cost billions of dollars to shift existing systems to other frequencies.[30]

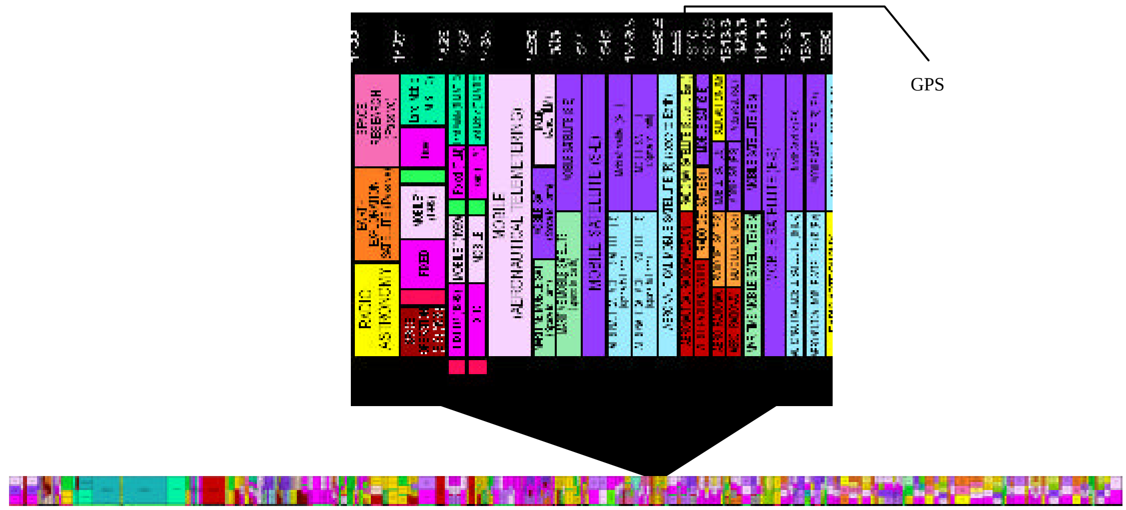

FIGURE 6 THE CROWDED FREQUENCY SPECTRUM

The frequency bands supporting ground forces today provide insufficient capability to transmit the large amounts of data over the distances and terrain needed by Objective Force elements. The majority of communications systems currently resident in the division operate in the Very High Frequency (VHF) and UHF portions of the spectrum (30-2500 MHz) and deliver primarily voice communication and some data exchange. VHF supports line of sight radios that have worked well for command and control of units operating in close proximity. However, the requirement to concentrate forces to enable communication does not fit the Objective Force Concept. Existing frequencies used at division and below provide the capacity for limited data exchange and verbal command and control, while providing good penetration of many of the environmental conditions commonly found on the battlefield like rain smoke and foliage. These frequencies also operate with relatively small antennas and radios, which are important for mobile ground forces.

TODAY'S SATCOM CANNOT MEET THE VISION FOR TOMORROW

COMMUNICATIONS SHORTFALLS

Shortfalls in communications capability continue to increase in spite of increasing capacity on MILSATCOM systems with each new generation launched. The most recent data point in 2002 showed that military satellite communications satisfied only 35 percent of the satellite communications needs for Operation ENDURING FREEDOM.[31] By 2010 the first Objective Force units with enhanced battlefield sensors, will be collecting orders of magnitude more data to provide greater fidelity, which will in turn require larger communication capacity. An example

from the commercial world of space imaging helps illustrate the magnitude of the problem, compounded in national satellite systems by higher resolution and larger data files.

To receive a single black and white photograph from space by the commercial imaging system QuickBird requires 1,600Mb of data be transmitted.[32] While the black and white photo is useful to the warfighter, viewing the same scene in hundreds or thousands of bands with hyper-spectral sensors enables the warfighter to identify camouflage, decoys, chemical agents, locations where the earth has been disturbed and much more. A hyper-spectral imager collects the same amount of data for each band imaged, as was collected for the black and white image, so a one-thousand band imager would need to transmit 1.6 Terabits[33] of information for the same point on the ground.

As Objective Force units deploy, they require continuous high-bandwidth communications enroute to update threat information and continue collaborative planning. Accurate data from space-based sensors provide Objective Forces the agility to land out of contact with the enemy and move directly into offensive operations. Few deployment platforms possess the long-range communications to support the deploying force. Mobile platforms currently equipped with satellite communication are most likely to be equipped with UHF satellite communications, if they have satellite communication capability at all. The scarcity of available channels and the low data rate of UHF make this existing capability an unlikely solution for the Objective Force.

Contrast the 16Kbs data rate in an existing UHF link to the data output from a single Global Hawk unmanned aerial vehicle, already able to communicate at 274 Mbs, and is expected to consume 1Gigabyte of bandwidth by 2010.[34] Already the requirements for bandwidth are huge. "During Operation Enduring Freedom (OEF) Global Hawk consumed five times the total bandwidth used by the entire United States military in the Gulf war."[35] Objective Force units are not only constrained by the total satellite communication system capacity but within the available bandwidth it must compete with the growing requirements of the other services and governmental agencies. Within an area of operations, the Combatant Commander uses his Director for Command, Control, Communications and Computer Systems (J6) and the Regional Satellite Support Center (RSSC) to allocate his apportioned bandwidth in accordance with theater priorities and requests augmentation through the Joint Staff for critical shortages. The Joint Staff may allocate additional resources by taking bandwidth from other theaters or by directing the Defense Information Systems Agency to attempt procurement of additional spectrum from commercial sources. Combatant Commanders can be forced to choose between systems, capabilities and coverage areas when insufficient bandwidth exists for simultaneous operations.

Current needs for space-based communications are increasing faster than the capability to provide satellite communication. The Combatant Commander of Pacific Command noted in Congressional testimony that "New platforms are producing an increasing flow of data, but our ability to exploit this data has not kept pace." He then went on to site "insufficient communications" as one of the key shortfalls.[36] These "bit rate" shortfalls to the ground combat soldier have a direct correlation with the ability to maintain sufficient information dominance to keep our forces alive. For example, some friendly force losses in Afghanistan may have been avoided, if the capability existed to fuse, process and transmit information already in hand to the point on the battlefield where the knowledge would make a difference.[37]

For the Objective Force to maintain information dominance, data and more importantly knowledge throughput to the deploying force must increase. Information must be processed, synthesized, and forwarded in real time. Smart sensors must know where to probe and intelligent systems must be able to extract critical information and forward the data in a compressed format. The solution to these problems will require a combination of increased capability, smarter processing, and appetite suppression. Today, systems collect much more information than they process, and they process more than they make available to the tactical commander. Deploying Objective Force units will not only need to reach forward to maintain situational awareness of the operational environment, but will also require simultaneous reach-back to supporting analysis structures at its deployment base. An increase in wideband capability is necessary for truly seamless information flow during the transition from home station through deployment.

DEALING WITH REALITY

Current satellite communication capabilities cannot meet the evolving Objective Force demands. A rough estimate of an individual Future Combat Systems (FCS) communications needs underlines the inability to provide sufficient data to Objective Force units on the move with today's systems.[38] Vehicles separated from line of sight communications have a host of data needs like those shown in Table 1 that are best satisfied through overhead systems. This data requirement alone requires 1,000Kbs circuits, while the primary capability to provide mobile data comes from UHF systems at 16Kbs.

Voice Command And Control	Collaborative Planning
Friendly Force Positions and status	Common Relevant Picture
System Logistic And Support Data	Weather And Micro Forecast Data
Missile Warning	Chem/Bio Hazards, Downwind Messages
Requests For Long-Range & Supporting Fires	Precision Engagement Support
Graphical Control Measures	Enemy Locations, Capabilities & Intentions
Long-Range Sensor Data, Target Locations	Imagery, Digital Terrain Updates

TABLE 1 OBJECTIVE FORCE FUTURE COMBAT SYSTEM DATA NEEDS

The leap from today's Army to the desired Objective Force communication capabilities appears to be beyond the grasp of the initial effort. The concept for the Objective Force Unit of Action calls for the integration of communications capabilities into Future Combat System Vehicles and its soldiers to eliminate dedicated signal systems and associate personnel. The October 2002 Objective Force draft approved for planning reflects a recognition that current technology and communications capabilities cannot provide wideband satellite communication on the move in time for the Block 1 fielding of the Future Combat System. As a replacement for wideband satellite communication on the move, the Unit of Action plan grew by forty-eight personnel, fifteen vehicles, five robotic vehicles, and associated equipment.[39] The addition of this signal company increases the logistic support required for the Unit of Action (including medics, mechanics, fuel, food and water consumption etc.) and ultimately requires more airlift, while creating a drag on its deployability and agility in the field. This initial Block I Objective Force has a marked improvement in information capabilities, but remains a far cry from the capabilities described in the Army Chief of Staff's vision.

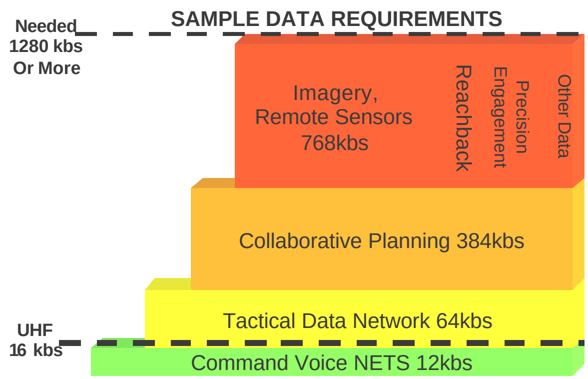

FIGURE 7 COMBAT VEHICLE CUMULATIVE DATA NEEDS

MUD TO SPACE – COMPLEX SOLUTIONS FOR COMPLEX PROBLEMS

Solving the Objective Force information needs at the warfighter level requires visionary solutions, unaffected by the cultures and biases of today's organizations and programmatics. Solutions to this challenge are expensive, require changes that cut across traditional areas of responsibility, and require technologies that continue to change at a breathtaking pace. But this should not come as a surprise. Acquisition strategies must plan for technology insertion, upgrades, and programmed replacements, while executing best value purchasing policies. There is no single solution or program office that can meet the Army's needs. Some of the solutions will come from the joint environment, while others must come from other agencies. For solutions to work, they must comprehensively address changes throughout the network of architectures that create the system. These changes should start at the birth of data where it is first collected and continue to the purging or archiving of the data, when the warfighters needs are satisfied. In addition to addressing changes to the data itself, the systems of hardware, software, formats, linkages and human interfaces of the architectures must be addressed as well.

Data Level Solutions – Reducing Demand And Enabling Data Interchange

At the point of data creation the Objective Force needs a strong set of standards and formats in order to enable rapid data interchange between network components. An unattended ground sensor should be able to pass its data directly to weapons platforms from any service without concerns about programming language, data elements, or measurement standards. Strong enforcement of standards across the Department of Defense will simplify network development and data interchange. The National Space Security Architect established a long-range plan as an outgrowth of its Mission Information Management (MIM) Information Management Architecture (IMA) study[40] to bring data generating systems into a standard architecture that would result not only in synergistic effects, but long-term cost savings as well. The major problem with this plan is that it lacks a powerful governing board to arbitrate changes to the standards or an enforcement mechanism, to keep programs in compliance.

Once collected, data must be transmitted. Currently there is little incentive for program developers to develop systems that preprocess data before transmission to reduce amount of data. Program developers largely focus on their program or sensor cost and not on the network-wide costs or tradeoffs, which could result in a cascading of costs to the greater system. Incentives must exist in program management to minimize the data stream from the hundreds of battlefield sensors. Compression techniques or target recognition software must

use critical information requirements to filter data collected and only forward data of interest for further processing. Total end-to-end understanding and control of the system being developed would enable such management decisions and acquisition trades.

Terminal Solutions – Platform Integration

Soldier Systems

At the soldier's level the communications architecture should work for the soldier and integrate easily into each task. The Army has recognized the need for wireless high data rate communications in vehicles and for wearable soldier systems. Its Short-Range High Data Rate Wireless Communications solicitation seeks bids to develop a wireless 100-megabyte per second network to connect dismounted soldiers to their vehicle networks and to each other over short distances.[41] This network allows soldiers conducting operations outside their vehicles to access onboard knowledge systems and use the higher power communications systems on the vehicle to pass images, targets and threat data to and from the network.

Objective Force soldiers need a personal communications device that stays with him or her at all times. During Operation ENDURING FREEDOM U.S. soldiers dragged around large bulky radios with limited ranges, while Al Qaida members purchased satellite cell phones to connected with one of the most powerful communications satellite on orbit. Such phones were no larger than the typical discount cellular phone sold in this country but can connect directly with other phones without going through the cellular system. When outside of direct contact with the number dialed the phones automatically connect with the local cellular service. When no cellular service is available the phones connect directly to a satellite to route the call. The lead in technology innovation and application should not rest with our adversaries. If every Department of Defense members possessed such devices, the individual handset cost would dramatically decline. Making these phones a part of everyday duties would enable rapid recall of soldiers, facilitate daily operations, increase safety, and eliminate millions of dollars in current cell phone contracts. Off-duty personal calls could be encouraged with calls charged directly to the soldiers pay account at a nominal rate to help persuade soldiers to keep the device available at all times. Building pager and Global Positioning System devices in the phone could solve blue force tracking issues by providing the location of each soldier on the battlefield.[42] A built in pager could provide missile warning to those in the threat fan or chemical warning to those in a downwind pattern.

Vehicle Systems

Meeting the needs of Objective Force combat vehicle communications represents a more difficult problem requiring multi-band solutions with smart processing software. Objective Force Future Combat Systems rolling off transport aircraft and sealift must arrive connected to a global information grid, the sensor network and be fully aware of the tactical and operational situation on the battlefield. While in transit to the area of operations, combat systems must update and pass data across a network compatible with the transport aircraft. Conformal antennas on the aircraft surface could provide connectivity enroute. Future Combat Systems must have self-organizing and self-healing communication networks, which transfer data from peer to peer when line of sight links are available and automatically search for earth, air and space links when other vehicles are out of sight. Conformal phased array antennas with no moving parts, electronically steered while on the move, provide the ability to switch seamlessly between data sources.[43] The Joint Tactical Radio System and Warfighter Information Network-Tactical are two new challenging programs working to design and build the hardware needed to support some of these Objective Force needs.

Bandwidth Solutions – Maximizing Data Pipes To Get The Message Through

Internet Protocol and Packet Data

Currently, most military communications use dedicated communications pipes, which will become unsupportable in the future due to their inefficient use of the electromagnetic spectrum. Objective Force Communications must transition most of these systems[44] to a smart Internet Protocol (IP) based network to allow data to be sent as packets similar to Internet traffic. This packet approach enables each communications pipeline to service many users and allows the throughput of the channel to be maximized. Large packetized data files are sent over multiple streams for reassembly at destination. Encrypted packets must provide multilevel security and smart dithering of data. Automatic dithering reduces the amount of data passed to minimum essential elements when the network capability is restricted. This allows for the graceful degradation of the system when communications nodes are operating at reduced capability or blocked. Multi-band radios like the Joint Tactical Radio System will provide seamless switching between jammed and open channels. Smart dithering and prioritization of the data streams ensure that the most critical data can always get through. This thinning of the data becomes critical when units are on the move or during periods of bad weather. A future combat system traveling down a road in Bosnia could link to an EHF satellite to enable large data transfers. As it starts to rain, EHF communications dramatically drop off and as the vehicle passes into a wooded section of the road the EHF signal is lost. As the primary signal fades the onboard

communications would automatically select a different satellite or use the strongest of the remaining signals and continue the download of critical packets. In this case UHF communications with their rain penetrating characteristics continue to transmit critical information at a much reduced data rate. The systems above would prioritize data including threats and warnings to friendly forces first.

Frequency Reuse

The electromagnetic spectrum is key terrain for the Objective Force. Maximizing the use of available bandwidth in the spectrum can provide a marked advantage to the Future Combat System when sufficient information is passed to meet the combat needs. Unfortunately, the requirements on this fixed number of radio frequencies continue to rise while the available frequencies are fixed by the laws of physics. Given that no additional spectrum can be created, the need for communications must be filled by using available frequencies more efficiently and more creatively. Frequency reuse multiplies bandwidth by using the same frequency multiple times. Normally two satellite radios can not use the same frequency or they would cause interference and jam each others signal. Satellite antennas that focus on a small area called a cell disregard similar frequencies coming from adjacent cells allowing the frequency to be reused in every cell created. Figure 9 includes an example of four frequencies being reused in multiple cells to maximize the use of the available bandwidth. Each frequency is used only once within a cell and is kept separate from other users on the same frequency by the cellular pattern. Some of the newest commercial satellites already use this technology to serve a larger subscriber base.

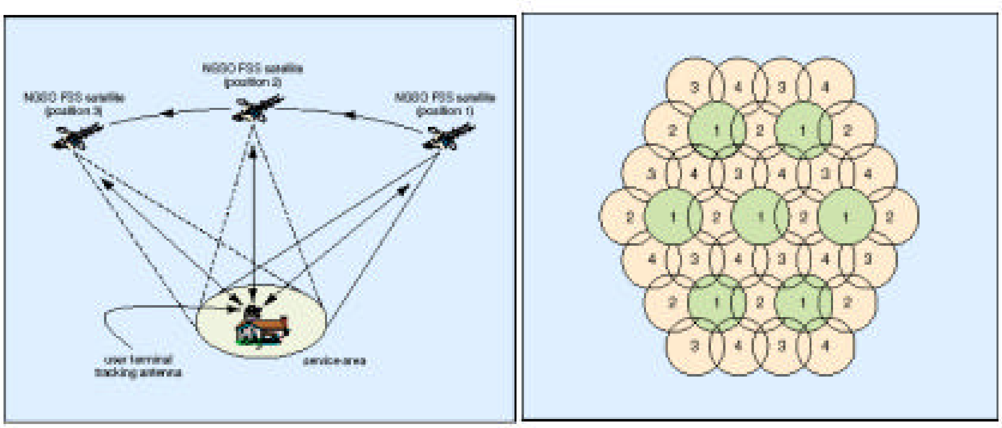

FIGURE 8 MULTIPLE LOOK ANGLES & FREQUENCY REUSE

Commercial Bandwidth

One way to deal with the lack of spectrum is to buy satellite time from commercial providers. Commercial satellite communications are more helpful in providing links to fixed command and control sites like the one United States military forces established at the Kandahar airport in Afghanistan. This is due to several reasons. Most commercial satellite systems are designed to support fixed locations rather than highly mobile users and do not have the capability to deal challenges mobile users present. Other problems with commercial system include their lack of hardening from attack, difficulty in dealing with military encryption systems and their need for hardware separate from that fielded to military forces.[45] In addition to these problems, there is no assurance that commercial providers will have capacity available to sell.[46] Taking several proactive steps will mitigate these difficulties and enable commercial communications to provide part of the answer.

Instead of relying on the communications spot market the Defense Information Systems Agency should purchase large blocks of frequency in areas where military operations are likely. Long-term contracts can be negotiated at much lower rates and will ensure communications are available when needed. These commercial satellites can provide much of the communications needed for large headquarters and fixed sites, which are not served by fiber connections leaving the military satellites for mobile users.[47] Agreements with commercial providers for back up satellite command and control and satellite hardening requirements would provide greater assurance of availability in times of conflict. Working closely with commercial providers may enable the military to add dedicated transponders to commercial satellites, which have available power and space onboard the satellite bus. These additional assets could provide redundancy and robustness to the overall constellation with relatively small costs. The addition of cross-linking capabilities to new commercial satellites would enable these commercial satellites to integrate into the global network to provide more direct support. More importantly new military terminals must be built with the ability to receive and transmit on commercial frequencies so new radios are not required when we are able to augment our capabilities with commercial spectrum.

SATELLITE SOLUTIONS AND SURROGATES

Satellite Design

At the space end of the communications problem satellites and satellite constellations must be designed to support the operational needs. Satellites need onboard processors to support network management and routing of packetized data. These satellites would become a

space based network computer server to push the right packets to the right users on the right frequencies to maximize throughput and ensure delivery. Satellite themselves must be cross-linked to form a self-managing network that reroutes traffic to avoid congestion and blockages of the communications signal. A space based communications backbone could create a nearly limitless data pipeline using laser communications to increase bandwidth within the network. Laser links could transmit data packets between satellites for transmission to the ground using traditional frequencies and link high altitude aircraft and airships with laser signals. Satellites must be built with a maximize the number of narrow spot beams. Spot beams increase the signal power to the user, reduce jamming threats and allow multiple users who are geographically separated to use the same frequency without interference virtually multiplying the usable bandwidth by the number of spot beams. Flying multi-band satellites would enable ground, sea, and air-based equipment with stabilized antenna systems to seamlessly switch on the move from one band to the next without having to search for and reacquire a lock on another satellite. Multi-band satellites can be single large satellites or merely appear as a single satellite by flying clusters of micro satellites in a precision orbit. Giant antennas in space, larger than a football field, would enable smaller low power hand held and wearable devices to communicate via space. These complex antenna structures could be assembled and mated in space at the International Space Station, thus reducing the costs and risks involved with deploying the intricate engineering structures robotically. Future satellites should be designed for on orbit repair and upgrade. Micro satellites could repair and refuel these large investments in national infrastructure, similar to the way the Hubble Telescope has been repaired and upgraded using astronauts from the space shuttle. Geosynchronous satellites provide limited coverage for mobile users at high latitudes, in urban canyons and in complex terrain due to the need of the vehicles antenna to be able to see the satellite. One way to overcome this “look angle” problem is to augment the geosynchronous network with a robust low or medium earth orbit constellation that can provide the high look angles needed to ensure data delivery. [48] Because these satellites are closer to the earth they can transmit more powerful signals to ground receivers and receive weaker low power signals in return. In addition to power benefits these closer satellites can reuse the frequency spectrum as was described in the spot beam characteristics above. To track these satellites moving at 17,000 miles per hour, vehicle antenna systems must be extremely agile and ideally would consist of phased arrays that are electronically steered to compensate for vehicle movement. Space systems can be augmented by high altitude systems which appear as satellites from the ground force prospective.

Pseudo Satellites

Complementing the space segment of the communications network with a suite of high altitude platforms would contribute to the robustness of the communications architecture. One of the most promising platforms is the High Altitude Airship. This rigid blimp-like craft more than two football fields in length would operate at altitudes over 70,000 feet for one to two years before returning to home station. From a communication terminal's perspective the airship would appear as a stationary satellite with an advantage that the airship could be placed where needed over a theater of operations without the limitations of orbital mechanics. Another advantage of the High Altitude Airship is that it can return to earth for repair or upgrade. Data needed by the Future Combat System would be beamed by laser from satellites to receivers on the top of the High Altitude Airship, which would convert the data to UHF, SHF and EHF packages for delivery to vehicles on the ground. This hybrid space/high-altitude design provides several advantages. They increase the number of look angles, would allow the user to get data blocked by terrain, vegetation or buildings. Airships or other high altitude unmanned aerial vehicles can be positioned at any point over the battlefield that can be protected and can carry additional sensors to support Objective Forces. Most importantly, pseudo-satellites also have the capability to multiply bandwidth available to the warfighter through frequency reuse as part of a robust system of systems to meet Objective Force needs.

CONCLUSION

> The capacity to produce relevant knowledge will meter the tempo of theater operations. I believe the difficulty of gathering the information needed for high tempo, largely scale, multidimensional and noncontiguous operations is largely underestimated…If Army units are to fight off the ramp, they must have situational understanding off the ramp. I suspect that there is an important delta between the capability projected to be available by 2015 and that which will be required… If our concepts depend on purpose oriented networks and knowledge enabled organizations, we must invest in the communications that will enable them.[49]

The Objective Force Concept is a visionary change in future ground combat operations. When the vision comes to fruition, it will provide a critical capability to the United States as it seeks to ensure peace and security in a changing world. Pivotal to the forces' effectiveness are the space enablers to tie together fast moving agile forces, dispersed across the battlefield. Of the space enablers, satellite communications play an essential role in information dominance and success. However, existing satellite communications systems designed and built for Cold

War needs are woefully inadequate for high technology digital warfare, while ground-based systems cannot support the mobility, agility, and speed expected of these forces. The growth of communications requirements needed to support Future Combat Systems and the Objective Force requires complex multi-echelon solutions, with fundamental changes from the smallest data bit to the largest satellite 22,300 miles in space. Solutions will not be easy or cheap, but require a strong hand to ensure the multiple acquisition systems, doctrine, and requirements processes synchronize in support of a clear objective.

WORD COUNT =8,992

ENDNOTES

[1] Joseph M. Cosumano Jr., “Space a Continually Growing Mission Area,” Army Space Journal, Fall 2002, 2.

[2] Eric K. Shinseki, Concepts for the Objective Force. White Paper, The Pentagon, Washington D.C. October 2001; Available from < http://www.army.mil/features/WhitePaper/ObjectiveForceWhitePaper.pdf>; Internet; accessed 30 March 2003.

[3] Eric K. Shinseki and Thomas E. White, “Transformation Roadmap,” 28 June 2002; available from <http://www.army.mil/vision/Transformation_Roadmap.pdf>; Internet; accessed 1 April 2003, E-1.

[4] David A. Martin, “Artillery Ammunition in the Korean War,” ALOG, (Sep/Oct 1998); available from <http://www.armc.army.mil/ALOG/issues/SepOct98/MS297.htm>; Internet; accessed on 15 February 2003.

[5] COL Bill Pierce my advisor on this project notes that precision strikes may not have the same psychological effect on the enemy than that caused by the more random devastation caused by tons of unguided bombs tumbling from a B-52. While relatively little has been written at the Army War College on this topic a search of the student papers at the Air War College provides numerous papers supporting both sides of this argument. The larger preponderance of these papers argue that precision strike has a psychological deterrent of its own.

[6] Keith Epstein, “'Fog' Obscuring U.S. Military Vision” Tampa Tribune MARCH 7, 2002; available from < http://www.globalsecurity.org/org/news/2002/020307-attack01.htm >; Internet: accessed On 7 April 2003.

[7] Ibid.

[8] Eric K. Shinseki and Thomas E. White, “Transformation Roadmap,”., 14.

[9] Bandwidth is a measurement of how much information can be carried over a communications link. In satellite communications, bandwidth is the width of the range of frequencies that an electronic signal occupies. Bandwidth is expressed as data speed in bits per second (bps).. A typical telephone call uses a bandwidth of approximately three to four kilohertz (3-4 kHz); while a television broadcast signal has a bandwidth two thousand times greater of six megahertz (6 MHz).

[10] Kurt A. Klausner, “Command and Control of Air and Space Forces Requires Significant Attention to Bandwidth,” Air & Space Power Journal, Winter 2002, available from <http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/win02/klausner.html>, Internet; accessed 21 January 2003.

[11] Units of Action are brigade sized forces capable of combined arms operation within a 75 km radius of operations executing Full Spectrum capabilities. The Army’s UA will be part of a joint team that is decisive in any operation, against any level threat, in any environment. This team must be strategically and operationally responsive, rapidly deployable, able to change patterns of operations faster than the enemy can respond, and adjust to enemy changes of operations faster than he can exploit them. The hallmarks of UA operations will be the

significant ability to develop situations out of contact, come at the enemy in unexpected ways, use teaming with leader initiative, maneuver to positions of advantage with speed and agility, engage enemy forces beyond the range of their weapons, destroying them with enhanced fires, and assaulting at times and places of our choosing. Although not necessarily sequential, it is the combination of fires (precision and volume) and maneuver, and the tactical assault that makes the enemy's problem so difficult. The cumulative effect of simultaneous, multi-dimensional operations will be to dominate an adversary, enabling friendly forces to destroy, dislocate and disintegrate him, and transition to the next engagement. TRADOC Pamphlet 325-3-90 Unit of Action O & O Plan.

[12] Paul Sass and Jim Freebersyser, FCS Communications Technology for the Objective Force, MITRE Technical Paper March 2002; available from <http://www.mitre.org/support/papers/tech_papers_02/>, Internet; accessed 25 March 2003, 2.1.

[13] "Army Space Reference Text," Space Division, Headquarters, Army Training and Doctrine Command; available from <http://www-tradoc.army.mil/dcscd/spaceweb/chap07b.html>; Internet; accessed 1 April 2003.

[14] "Executive Summary of the Commercial Satellite Communications (SATCOM) Report," Technical Report delivered to Naval Space Command, available at <http://fas.org/spp/military/docops/navy/commrept/>, Internet; accessed 26 February 2003.

[15] Geosynchronous refers to satellites which complete one orbit of the earth in 24 hours matching the earths rotation. These satellites appear stationary from the earths surface. To match the earths rotation satellites must orbit at 36,000 kilometers above the earth.

[16] Navy Fact Sheet, "Navy Communications Satellite Programs" available from <http://www.pmw146.navy.mil>; Internet; accessed 23 Feb 03.

[17] Keith Hollinger. "UHF SATCOM Questions." Army Space Command Electronic mail messages to Tim Coffin <timothy.coffin@us.army.mil>, 4 March 2003.

[18] Congress, House of Representatives, Armed Services Committee, Statement by Admiral Dennis C. Blair U.S. Commander In Chief U.S. Pacific Command, On U.S. Pacific Command Posture, 107th Cong., 20 March 2002 available from <http://www.house.gov/hasc/opening statementsandpressreleases/107thcongress/02-03-20blair.html>, Internet; accessed 25 Feb 2003.

[19] Justin Ray, "Delta 4 Rocket Successfully Begins Military Service," Spaceflight Now, 10 March 2003; available from < http://www.spaceflightnow.com/>; Internet; accessed 1 April 2003.

[20] "Executive Summary of the Commercial Satellite Communications (SATCOM) Report," Technical Report delivered to Naval Space Command, available at <http://fas.org/spp/military/docops/navy/commrept/>, Internet; accessed 26 February 2003.

[21] U.S. Naval Institute and AFCEA, "Information Technology for the 21st Century." Online briefing with note pages; available from <http://www.stl.nps.navy.mil/it21_files/outline.htm>, Internet; accessed 26 February 2003.

[22] “Space Support Reference Book”, Army Space Command; undated; COM-26 8-20-97.

[23] Lockheed Martin Fact Sheet, “MILSTAR Satellite Overview,” 22 February 2001, available at <http://spaceflightnow.com/titan/b41/010222milstar.html>, Internet; accessed 15 February 2003.

[24] “MILSTAR,” Encyclopedia Astronautica; available from <http://www.fplib.ru/partners/mwade/craft/milstar.htm>; Internet; accessed 15 February 2003.

[25] “Executive Summary of the Commercial Satellite Communications (SATCOM) Report,” Technical Report delivered to Naval Space Command, available at <http://fas.org/spp/military/docops/navy/commrept/>, Internet; accessed 26 February 2003.

[26] Carol Welsch, “Battlespace Bandwidth” briefing HQ U.S. Air Force Space Programs and Integration Division. 19 November 2002; available from <http://www.sspi.org/art2/presentations/Welsch_Presentation.PDF>; Internet; accessed 1 March 2003.

[27] Relative Capacity of UHF, SHF, EHF Chart derived from data in the “U.S. Army Space Reference Text 2000,” U.S. Army Space and Missile Defense Command; May 2000:151-185.

[28] Joseph Capps, “Spectrum 101 for the Acquisition Professional,” briefing slides with scripted commentary. Director, Army Spectrum Management, May 2002.

[29] Congress, House of Representatives, Committee on Commerce Subcommittee on Telecommunications and Finance, Briefing by Brigadier General Michael W. Ackerman, USA Vice Director, Command, Control, Communications, and Computer Systems (J6) The Joint Staff accessed 3 March 2003 at http://spectrum.nawcad.navy.mil/group1.html.

[30] GPS Frequency figure developed from U.S. Department of Commerce, United States Frequency Allocations, March 1996, available at <http://www.ntia.doc.gov/osmhome/allochrt.pdf>; Internet; accessed 25 March 2003.

[31] Welsch.

[32] “Quickbird Imagery Products FAQ,” Digital Globe, Longmont Colorado, available at <www.digitalglobe.com>; Internet; accessed 30 December 2002.

[33] A Terabyte is a Trillion bytes or more accurately 1,099,511,627,776 bytes.

[34] “RQ-4A Global Hawk (Tier II+ HAE UAV)” Federation of American Scientist; Available from <http://www.fas.org/irp/program/collect/global_hawk.htm>; Internet; accessed 15 February 2003.

[35] Klausner.

[36] Congress, Statement by Admiral Dennis C. Blair.

[37] Authors interpretation of problems in data flow to and from the critical point on the battlefield formulated after discussions and reviewing Predator video tape of U.S. casualties in

Afghanistan. Issues relating to this discussion are detailed in Andrew N. Millani, Pitfalls of Technology: A Case Study Of The Battle On Takur Ghar. Strategic Research Project. (Carlisle Barracks: U.S. Army War College, 10 April 2003).

[38] Figure 9 was developed from materials found in U.S. Naval Institute and AFCEA, "Information Technology for the 21st Century." Online Briefing with note pages; available from <http://www.stl.nps.navy.mil/it21_files/outline.htm>, Internet; accessed 26 February 2003.

[39] Pete Zielinski, "Unit of Action (UA) Design," briefing slides with notes, U.S. Department of the Army, Training and Doctrine Command, November 2002, available from <http://cbnet/orgs/usacsl/ExReports.asp>; Internet; accessed 25 February 2003.

[40] Marian Cherry and Barry Bryan, "MIM IMA Transition Plan," briefing slides and notes pages, Office of the Secretary of Defense, Pentagon, 28 June 2001.

[41] Department of Defense, Small Business Innovation Research Resource Center, Army 03-T05 "Short-Range High Data Rate Wireless Communications," available from <http://www.dodsbir.com/solicitation/army03.htm>, Internet; accessed 19 March 2003.

[42] Blue Force Tracking involves locating friendly forces on the battlefield to avoid fratricide issues.

[43] Sandra I Erwin, "Army's Future Tactical Net Apt for High-Speed Combat," National Defense (October 2001); available from <http://www.nationaldefensemagazine.org/article.cfm?Id=609>, Internet; accessed 19 March 2003.

[44] Data channels which fill the communication channels near its full capacity are more efficient in dedicated pipelines as they do not require the header data needed to route and reassemble packetize data at its destination.

[45] Steven G. Fox, "The Dimming of Joint Vision 2020: A Concern That the Lack of Military Satellite Communications Will Impede the Future Force;" Strategic Research Project (Carlisle Barracks, U.S. Army War College, 28 February 2001), 19.

[46] U.S. Air Force, Scientific Advisory Board, "Availability and Survivability of Militarily Relevant Commercial Space Systems," Volume 1 summary, March 2002, 24.

[47] COL John Grobmeier, "Transforming Army Tactical Communications: Enabling the Future Combat System and U.S. Army Objective Force," briefing, available from< http://www.afcea-ftmonmouth.org/documents/part%203.pdf>, accessed 23 February 2003.

[48] Figure 10 is from S. Kirtay's article "Broadband Satellite System Technologies for Effective Use of the 12-30 Ghz Radio Spectrum," Electronics & Communication Engineering Journal, (April 2002). Also available at http://www.aegis-systems.co.uk/download/ecej1.pdf>, Internet. Accessed 27 March 2003.

[49] Huba Wass de Czege. "Wargaming Insights," Army, March 2003, 42.

BIBLIOGRAPHY

Associated Press < www.floridatoday.com/space/explore/stories/1999b/111399b.htm >. "Report: China Has Laser Defense Technology to Shoot Down Missiles." The Associated Press. 13 November 1999. Accessed on 30 January 2003.

Baehr, Brad, et al. "Space Control Operations and the U.S. Army." Military Review, vol. 81, no. 6, Nov./Dec. 2001, pp. 25-30.

Capps, Joseph. "Spectrum 101 for the Acquisition Professional" Briefing slides with scripted commentary. Director, Army Spectrum Management, May 2002.

Carey, Steve. An Executive Guide to Space: A Starting Point for Understanding Space in the Millennium. Santa Monica, CA: RAND, 2000.

Carlson, Bruce. "Protecting Global Utilities: Safeguarding the Next Millennium's Space-Based Public Services." Aerospace Power Journal, vol. 14, no. 2, Summer 2000, pp. 37-41.

Cavanaugh, John MG. "Synchronizing with the Objective Force", Army Communicator on-line (Summer 2002) Available from <http://www.gordon.army.mil/AC/sumr02/chsigcmt.htm >. Internet. Accessed 19 March 2003.

Chairman Joint Chiefs of Staff. National Military Strategy. Washington, D.C.: U.S. Government Printing Office, 1997.

Cherry, Marian and Barry Bryan. "MIM IMA Transition Plan." briefing slides and notes pages, Office of the Secretary of Defense: Pentagon, 28 June 2001.

Cheyenne Mountain Operations Center. "Satellite Box Score." Available at < https://www. cheyennemountain.af.mil/boxscore.htm >. Internet. Accessed 31 January 2003.

Cohen, William S. Space Policy. DOD Directive 3100.10. Washington D.C.: U.S. Department of Defense, 9 July 1999.

Collins, John M. Military Space Forces: The Next 50 Years. Washington D.C.: Brassey's, 1989.

Commission to Assess United States National Security Space Management and Organization. Pursuant to Public Law 106-65. 11 January 2001. Available from < http://intellnet.org/ resources/report_space_management_organization/ >. Accessed 31 January 2003.

Corey, Dan. "Intelligence Preparation of the Battlefield Needs Space." Military Review, vol. 81, no. 6, Nov./Dec. 2001, pp. 31-34.

DeKok, Roger. "Toward Air and Space Integration – The Space Roadmap." Invited Speaker, Beverly Hills CA, Air Force Association National Symposium, 16 November 2001. Available from < http://www.aef.org/pub/dekok1101.asp >. Internet. Accessed 31 January 2003.

Department of Defense, Small Business Innovation Research Resource Center. Army 03-T05 "Short-Range High Data Rate Wireless Communications" Available from <http://www.dodsbir.com/solicitation/army03.htm>. Internet. Accessed 19 March 2003.

Dept. of Defense Directive 3100.10. Department of Defense Space Policy. July 9, 1999.

Directorate for Operational Plans and Joint Force Development, The Joint Staff. An Evolving Joint Perspective: US Joint Warfare and Crisis Resolution In the 21st Century The Pentagon, Washington D.C. 28 January 2003

Encyclopedia Astronautica. "MILSTAR." Available from <http://www.fplib.ru/partners/mwade/craft/milstar.htm>. Internet. Accessed 15 February 2003.

Epstein, Keith. "'Fog' Obscuring U.S. Military Vision" Tampa Tribune MARCH 7, 2002; Available from < http://www.globalsecurity.org/org/news/2002/020307-attack01.htm >. Internet. Accessed 7 April 2003.

Erwin, Sandra I. "Army's Future Tactical Net Apt for High-Speed Combat." National Defense (October 2001). Available from <http://www.nationaldefensemagazine.org/article.cfm?Id=609>. Accessed 19 March 2003.

Estes, Howell M. III. "United States Space Command Vision for 2020." February 1997. Available from < http://fas.org/spp/military/docops/usspac/visbook.pdf >. Internet. Accessed 31 January 2003.

"Executive Summary of the Commercial Satellite Communications (SATCOM) Report." Technical Report delivered to Naval Space Command. Available at <http://fas.org/spp/military/docops/navy/commrept/>. Internet. Accessed 26 February 2003.

Federation of American Scientist. "RQ-4A Global Hawk (Tier II+ HAE UAV)" Available from <http://www.fas.org/irp/program/collect/global_hawk.htm>. Accessed 15 February 2003.

Federation of American Scientists. Space Policy Project. On-Line. Jan. 7, 2002. Available at:< http://www.fas.org/spp/ >. Internet. Accessed 31 January 2003.

Fox, Steven G. The Dimming of Joint Vision 2020: A Concern That the Lack of Military Satellite Communications Will Impede the Future Force. Strategic Research Project. Carlisle Barracks: U.S. Army War College, 28 February 2001.

Gertz, Bill. "Chinese Army is Building Laser Weapons. "The Washington Times, Washington, D.C., 3 November 1998.

Gertz, Bill. "Yeltsin Letter Reveals Anti-Satellite Weapons. "The Washington Times Washington, D.C. 7 Nov 1997

Gibson, Robert D. Space Power, the Revolution in Military Affairs. Carlisle Barracks, PA: Army War College, 2001.

Gonzales, Daniel. The Changing Role of the U.S. Military in Space. Santa Monica, CA: Rand, 1999.

Gray, Colin S and John B. Sheldon. "Space Power and the Revolution in Military Affairs: A Glass Half Full?" Airpower Journal, vol. 13, no. 3, Fall 1999, pp. 23-38.

Gray, Colin S. "The Influence of Space Power upon History." Comparative Strategy, vol. 15, no. 4, Oct./Dec. 1996, pp. 293-308.

Grobmeier, COL John. “Transforming Army Tactical Communications: Enabling the Future Combat System and U.S. Army Objective Force” Available from< http://www.afcea-ftmonmouth.org/documents/part%203.pdf>. Accessed 23 February 2003.

Handberg, Roger. Seeking New World Vistas: The Militarization of Space. Westport, CT: Praeger, 2000.

Hays, Peter, and Karl Mueller. “Going Boldly—Where?: Aerospace Integration, the Space Commission, and the Air Force’s Vision for Space.” Aerospace Power Journal 15, 1 (Spring 2001): 34-49.. Available at <http://www.airpower.maxwell.af.mil/airchronicles/apj/apj01/spr01/mueller.pdf. >. Internet. Accessed 31 January 2003.

Hays, Peter. "Going Boldly—Where? Aerospace Integration, the Space Commission, and the Air Force’s Vision for Space." Aerospace Power Journal, vol. 15, no. 1, Spring 2001, pp. 34-49.

Hollinger, Keith. “UHF SATCOM Questions.” Army Space Command Electronic mail messages to Tim Coffin <timothy.coffin@us.army.mil>. 4 March 2003.

Johnson, Dana J., Scott Pace and C. Bryan Gabbard. Space: Emerging Options for National Power. Santa Monica, CA: Rand, 1998.

Kirtay, S. “Broadband Satellite System Technologies for Effective Use of the 12-30 Ghz Radio Spectrum.” Electronics & Communication Engineering Journal. April 2002. Also available at http://www.aegis-systems.co.uk/download/ecej1.pdf>. Internet. Accessed 27 March 2003.

Klausner, Kurt A. “Command and Control of Air and Space Forces Requires Significant Attention to Bandwidth,” Air & Space Power Journal (Winter 2002) Available from <http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/win02/klausner.html>. Internet. Accessed 21 January 2003.

Lamb, John H. Space Control as a Critical Mission Area: Leveraging Space-Based Assets for the Joint Commander. Newport, RI: Joint Military Operations Dept., Naval War College, 2001.

Lambakis, Steven James. On the Edge of Earth: The Future of American Space Power. Lexington, KY: University Press of Kentucky, 2001.

Lockheed Martin Fact Sheet. “MILSTAR Satellite Overview.” 22 February 2001. Available at <http://spaceflightnow.com/titan/b41/010222milstar.html>. Internet. Accessed 15 February 2003.

Long Range Plan. Peterson AFB, Colo.: Headquarters US Space Command, 1998.

Long Range Plan: Implementing USSPACECOM Vision for 2020. Peterson AFB, CO, 1998.

Lord, Lance W. AFSPC: Space Commission and Beyond. Speech at the Air Force Association Nationional Symposium on Space, Beverly Hills, CA 15 November 2002. Available from < http://www.peterson.af.mil/hqafspc/Library/speeches/Speeches.asp?YearList=2002&SpeechChoice=29 >. Internet. Accessed 31 January 2003

Martin, David A. "Artillery Ammunition in the Korean War." ALOG, (Sep/Oct 1998): Available from <http://www.armc.army.mil/ALOG/issues/SepOct98/MS297.htm>. Internet. Accessed on 15 February 2003.

Matthews, Earl D. "U.S. Space Systems: A Critical Strength and Vulnerability." Ph. D. Diss., Newport, RI, Naval War College, 1996.

McKinley, Cynthia A. S. "The Guardians of Space: Organizing America's Space Assets for the Twenty-First Century." Aerospace Power Journal, vol. 14, no. 1, (Spring 2000): 37-45.

Millani, Andrew N. Pitfalls of Technology: A Case Study Of The Battle On Takur Ghar. Strategic Research Project. Carlisle Barracks: U.S. Army War College, 10 April 2003.

Moorman, Thomas S. Jr. "Space, A New Strategic Frontier." Airpower Journal Spring 1992. Available from < http://www.airpower.maxwell.af.mil/airchronicles/apj/moor.html >. Internet. Accessed on 30 January 2003.

National Aeronautics and Space Act of 1958. U.S. Code. Vol. 42, Sec. 2451(a) (1958). Available from < http://naca.larc.nasa.gov/space-act.html >. Accessed on 30 January 2003.

Oberg, Jim. Space Power Theory. U.S. Air Force Academy: Government Printing Office, 1999.

Preston, Bob. Plowshares and Power: The Military Use of Civil Space. Washington: National Defense University Press, 1994.

"Quickbird Imagery Products FAQ," Digital Globe, Longmont Colorado, available at <www.digitalglobe.com>, Internet. Accessed 30 December 2002.

Ray, Justin. "Delta 4 Rocket Successfully Begins Military Service," Spaceflight Now, 10 March 2003.

Reagan, Ronald. Presidential Directive on National Space Policy. Washington D.C.: The White House, 11 February 1988.

Richelson, Jeffery T. America's Secret Eyes In Space: The U.S. Keyhole Spy Satellite Program. New York: Harper and Row, 1990.

Rumsfeld, Donald H. "Secretary Rumsfeld Outlines Space Initiatives. "Press Conference, Washington D.C., 8 May 2001. Available from < http://www.defenselink.mil/news/May2001/t05082001_t0508spa.html >. Internet. Accessed 30 January 2003.

Sass, Paul, and Jim Freebersyser. FCS Communications Technology for the Objective Force. MITRE Technical Paper March 2002. Available from <http://www.mitre.org/support/papers/tech_papers_02/>. Internet. Accessed 25 March 2003.

"Satellite Self-Protection Equipment Attracts USAF Interest, Investment. "Aviation Week & Space Technology 16 August 1999: 26.

Scott, William B. "New Satellite Sensors Will Detect RF, Laser Attacks. "Aviation Week & Space Technology 2 August 1999: 57-8.

Shalikashvili, John M. Joint Vision 2010. Washington, D.C.: Chairman of the Joint Chiefs of Staff, 1997.

Shinseki, Eric K. Concepts for the Objective Force. White Paper, The Pentagon, Washington D.C. Available from < http://www.army.mil/features/WhitePaper/ObjectiveForce WhitePaper.pdf>. Internet. Accessed 30 March 2003.

Shinseki, Eric K. and Thomas E. White. "Transformation Roadmap." 28 June 2002. available from <http://www.army.mil/vision/Transformation_Roadmap.pdf>. Internet. Accessed 1 April 2003.

Smith, Senator Bob. "Space Power: What Is At Stake, What Will It Take." Lecture, Washington D.C., Center for Security Policy Roundtable, 11 December 2000. Available from <http://www.security-policy.org/papers/2001/01-P03.html >. Internet. Accessed 30 January 2003.

Sun Tzu. The Art of War. Edited by James Clavell. New York, NY: Delacorte Press, 1983.

Tirpak, John A. "The Space Commission Reports." Air Force Magazine 84, 3 (March 2001): 30-35. Database on-line. Available at < http://www.afa.org/magazine/March2001/0301 space.html>. Internet. Accessed 31 January 2003.

U.S. Air Force, MILSATCOM Joint Program Office. "Defense Satellite Communications System." Available at <http://www.losangeles.af.mil/SMC/MC/mcd.html>. Internet. Accessed 15 February 2003.

U.S. Air Force, Scientific Advisory Board. "Availability and Survivability of Militarily Relevant Commercial Space Systems": Volume 1 Summary. March 2002.

U.S. Army Science Board. Army Science Board Summer Study, Final report: Prioritizing Army Space Needs. Washington: Dept. of the Army, Assistant Secretary of the Army, Acquisitions, Logistics and Technology, 1999.

U.S. Commission to Assess United States National Security Space Management and Organization. Report of the Commission to Assess United States National Security Space Management and Organization. Washington: The Commission, 2001. (Also available at <http://www.defenselink.mil/pubs/space20010111.html >)

U.S. Congress. House of Representatives. Armed Services Committee. Statement by Admiral Dennis C. Blair U.S. Commander In Chief U.S. Pacific Command. On U.S. Pacific Command Posture, 107th. Cong., 20 March 2002. Available from <http://www.house .gov/hasc/openingstatementsandpressreleases/107thcongress/02-03-20blair.html>. Internet. Accessed 25 Feb 2003.

U.S. Department of Commerce. United States Frequency Allocations. March 1996. Available at <http://www.ntia.doc.gov/osmhome/allochrt.pdf>. Internet. Accessed 25 March 2003.

U.S. Department of the Army. Unit of Action (UA) Design. Training and Doctrine Command. November 2002. Available from <http://cbnet/orgs/usacsl/ExReports.asp>. Internet. Accessed 25 February 2003.

U.S. General Accounting Office. Defense Acquisitions: Improvements Needed in Military Space Systems' Planning and Education. Washington: GAO, 2000.

U.S. Naval Institute and AFCEA. "Information Technology for the 21st Century." Online Briefing with note pages. Available from. <http://www.stl.nps.navy.mil/it21_files/outline.htm>. Internet. Accessed 26 February 2003.

U.S. Space Command. Long Range Plan: Executive Summary. Peterson AFB, CO, 1998.

United Nations. "Technical Report on Space Debris". Available from <http://www.oosa.unvienna.org/isis/pub/sdtechrep1/>. Internet. Accessed 30 January 2003.

US Department of Defense, National Reconnaissance Office, Report of the National Commission for the Review of the National Reconnaissance Office, The NRO At The Crossroads, 1 November 2000.

Vision for 2020, United States Space Command, Colorado Springs, CO 1997

Wall, Robert. "Intelligence Lacking on Satellite Threats." Aviation Week & Space Technology 150, no. 9 (1 March 1999): 54-55.

Wass de Czege, Huba. "Wargaming Insights" Army, March 2003, 36-44.

Watts, Barry D. The Military Use Of Space: A Diagnostic Assessment. Washington D.C.: Center for Strategic and Budgetary Assessments, 2001.

Welsch, Carol. "Battlespace Bandwidth" Briefing HQ U.S. Air Force Space Programs and Integration Division. 19 November 2002. Available from <http://www.sspi.org/art2/presentations/Welsch_Presentation.PDF>. Internet. Accessed 1 March 2003.